HALF BRIDGE BIDIRECTIONAL DC-DC CONVERTER

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DECLARATION

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references"

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DECLARATION

"I hereby declared that I have read through this report entitle 'Half Bridge Bidirectional DC-DC Converter"

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ABSTRACT

Electrical applications that uses renewable energy needs a power converter in order to converts or limits the power from the renewable source to the load. Existing DC-DC Converter is capable of doing that but for a renewable energy like PV panel can only provide power when there is high intensity of sunlight. PV panel power will faded if the sky become cloudy or rain. In order to provide supply to the load without any interruption, Half-bridge Bidirectional DC-DC Converter (BDC) is introduced. The power intermittency issue of PV panel can be overcome with the aid of secondary supply. The control between the primary and secondary supply is done by the BDC. Half-bridge topology is selected for the BDC since it has simple yet reliable design. Half-bridge BDC topology will have a high voltage (HV) and low voltage (LV) side. PV panel at the HV side meanwhile, battery is at the LV side. BDC will either operate as a buck or boost converter according to the mode of operation require. The direction of the bidirectional current in the BDC will tell the mode of the BDC. If the bidirectional current is flowing from HV side to the load, BDC is in buck mode to reduce the voltage input to the level that similar to the load voltage. If the bidirectional current is flowing from the LV side to the load, BDC is in boost mode to step up the voltage up to the required level. PV panel voltage value is $18V$ meanwhile the battery nominal rating is $6V$. The load voltage is fixed at $12V$. The simulation of the system is done using MatLab Simulink and the results obtained are presented and discussed. The simulation results show that the voltage load remain constant even though the condition of the two source supply varied from power given in maximum to minimum. The mode of the BDC is changing according to the required mode. The battery capacity is increase when the BDC is in buck mode and shows that the bidirectional current flowing from HV side to load and LV side. If the battery capacity decrease, then the current is flowing in inverse direction. The value of the bidirectional current also can prove the mode of the BDC which is either negative (flow from LV to HV) or positive (flow from HV to LV).

ABSTRAK

Aplikasi elektrik yang menggunakan tenaga boleh diperbaharui memerlukan penukar kuasa untuk menukar atau membatasi kuasa dari sumber terbarukan kepada beban. Bekas DC-DC Converter mampu melakukan itu tetapi untuk tenaga boleh diperbaharui seperti panel PV hanya boleh memberi kuasa apabila terdapat intensiti cahaya matahari yang tinggi. Kuasa panel PV akan pudar jika langit menjadi berawan atau hujan. Untuk memberi bekalan kepada beban tanpa sebarang gangguan, Half-bridge Bidirectional DC-DC Converter (BDC) diperkenalkan. Isu pemecahan kuasa panel PV boleh diatasi dengan bantuan bekalan sekunder. Kawalan antara bekalan primer dan sekunder dilakukan oleh BDC. Topologi separa jambatan dipilih untuk BDC kerana ia mempunyai reka bentuk yang mudah namun boleh dipercayai. Topologi BDC separuh jambatan akan mempunyai bahagian voltan tinggi (HV) dan voltan rendah (LV). Sementara itu, panel PV di sebelah HV, bateri berada di sebelah LV. BDC sama ada beroperasi sebagai penaik atau penukar rangsang mengikut mod operasi yang diperlukan. Arah arus bidirectional di BDC akan memberitahu mod BDC. Jika arus bidirectional mengalir dari sisi HV ke beban, BDC adalah dalam mod buck untuk mengurangkan input voltan ke tahap yang sama dengan voltan beban. Jika arus bidirectional mengalir dari sisi LV ke beban, BDC berada dalam mod rangsangan untuk meningkatkan voltan sehingga tahap yang diperlukan. Nilai voltan panel PV ialah $18V$ manakala penarafan nominal bateri ialah $6V$. Voltan beban tetap pada $12V$. Simulasi sistem dilakukan menggunakan MatLab Simulink dan hasil yang diperoleh dibentangkan dan dibincangkan. Hasil simulasi menunjukkan bahawa beban voltan tetap malar walaupun keadaan bekalan dua sumber bervariasi dari kuasa yang diberikan secara maksimal ke minimum. Cara BDC berubah mengikut mod yang diperlukan. Kapasiti bateri meningkat apabila BDC berada dalam mod buck dan menunjukkan bahawa arus bidirectional mengalir dari sisi HV ke beban dan sisi LV. Sekiranya kapasiti bateri berkurangan, maka arus mengalir ke arah yang terbalik. Nilai semasa bidirectional juga boleh membuktikan mod BDC yang sama ada negatif (aliran dari LV ke HV) atau positif (aliran dari HV ke LV).

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INTRODUCTION

1.1 Overview

The Half Bridge Bidirectional DC-DC Converter project is to provide supply to the load with either a battery or solar without stopping the system when role of the power supplier changed. This chapter will discuss about the background of the project, the objectives, the scope and the problem statements of the project. Lastly, this chapter will describe about what each chapter has to offer.

1.2 Background

Power converters is one of the most important parts in photovoltaic system. The reason that they play an important role in transforming the different types of electricity, to make the electricity convenient to the end users. Since the solar cells produces DC type of electricity, there is room for various types of power converters [1]. Because of constantly growing energy demand, grid-connected photovoltaic systems are becoming more and more popular, and many country have permitted, encouraged, and even funded distributed-power-generation systems. Currently, solar panels are not very efficient with only about 12–20% efficiency in their ability to convert sunlight to electrical power. The efficiency can drop further due to other factors such as solar panel temperature and load conditions. In order to maximize the power derived from the solar panel, it is important to operate the panel at its optimal power point. To achieve this, the power electronics interface, connected between a solar panel and a load battery, is a pulse width modulator (PWM) DC-DC converter used to extract their maximum power from PV solar panel [2].

The main drawbacks of solar PV system is its high cost of installation for producing desired power level of electricity which is due to the high manufacturing cost of solar modules compounded with its low conversion efficiency. Most of the times, the power conversion system associated with the solar PV generating unit can cost up to 40% of the total cost. PV system, in general, is designed to deliver a specific amount of energy as per the requirement of the applications. Therefore, purchase and installation of all PV system will eventually be based on predicted or guaranteed energy production. To make the solar PV system commercially viable, the cost of unit generation of electricity from solar PV system needs to be reduced which, in turn, calls for the development of a low cost, high efficient power conversion systems or schemes for delivering required electrical power. Hence it is always critical to design the most appropriate power converters and to assess their performance to ensure maximum power capture from solar modules along with impeccable power quality, reliability and efficiency [3].

1.3 Problem Statement

The conventional of photovoltaic power system may use on-off directly control system. These system have a simple build and structures. However, they also have a significant drawback such as, there is no control applied on the charging state of the battery, which may result in large overcharge current and thus shorten the lifespan of the battery. The on-off state between the battery and the PV cannot provide supply to the load simultaneously. In additional, the operation of the load need to be stop in order to change the supply used to it. From the weakness of the conventional system, the bidirectional DC-DC converter is introduced.

1.4 Objectives

The objectives of this project are:

1. To design the Bidirectional DC-DC converter.
2. To design the switching method for the Bidirectional DC-DC converter.
3. To analyse the simulation and experiment results of the Bidirectional DC-DC converter with a PV source.
4. To implement the hardware of the Bidirectional DC-DC Converter.

1.5 Scope

This project will focus on the designing the Bidirectional DC-DC Converter using a feedback controller to decide the type of supply to be used for the load. This project will also be simulated using MatLab Simulink in order to simulate the converter switching method. Besides that, a hardware of this project will also be created after the process of simulating.

1.6 Chapter Organization

This report consist of six chapter and the chapters are listed below:

Chapter 1: Introduction

This chapter will explain about the project. It also consists of the problem statement of the project, the objective and project scope.

Chapter 2: Literature Review

This chapter will discuss about the other project, studies or research that is related with this project.

Chapter 3: Methodology

This chapter will explain about the methods that are used in conducting the project. In this chapter, the flow of works will be shown and explain.

Chapter 4: Result

This chapter will discuss about the result obtained from the beginning of the project up till now. It will show the progress of the project.

Chapter 5: Analysis and Discussion

This chapter will show the analysis that has been made according to the results obtained from the project and also discussions about the progress of the project. Any problem and overcome of the project will be stated in this chapter.

Chapter 6: Conclusion

This chapter will show the conclusion of the project and also the recommendations of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will discuss about the literature studies and researches that has been made during the process of understanding the project. The literature studies and researches are obtained either from journals, internet or from reference books. The literature studies are important to understand the basic concept of the project and the related information regarding the project. First is the study on the conventional Bidirectional DC-DC Converter (BDC) and then the topology for the BDC related to this project. Lastly, a switching method for the BDC will be discuss and conclusion is made.

2.2 Conventional DC-DC Converter

Before the ages of power semiconductor and other devices similar to it, converting the DC voltage supply to a higher value is by converting the it to AC by using a vibrator then followed by a step-up transformer and rectifier. This is only for low-power application. Meanwhile, to get the desired voltage for higher power application, an electric motor was used to drive the generator. These method is only use when there was no other alternative.

DC-DC power converters are employed in a variety of applications, including power supplies for personal computers, office equipment, spacecraft power system, laptop computers, and telecommunications equipment, as well as DC motor drives. The input to a DC-DC converter is an unregulated DC voltage. The converter produces a regulated output voltage, having a magnitude that differs from the input voltage. For example, in a computer off-line power supply, the $120V$ or $240V$ AC utility voltage is rectified, producing a DC voltage of approximately $170V$ or $340V$ respectively. A DC-DC converter then reduces the voltage to the regulated $5V$ or $3.3V$ required by the processor ICs [4].

2.2.1 Converter Circuit Topologies

The ability to decrease or increase the magnitude of the DC voltage and invert its polarity are what DC-DC converter are known for. Figure 2.1 illustrates several commonly used DC-DC converter circuits, along with their respective conversion ratios.

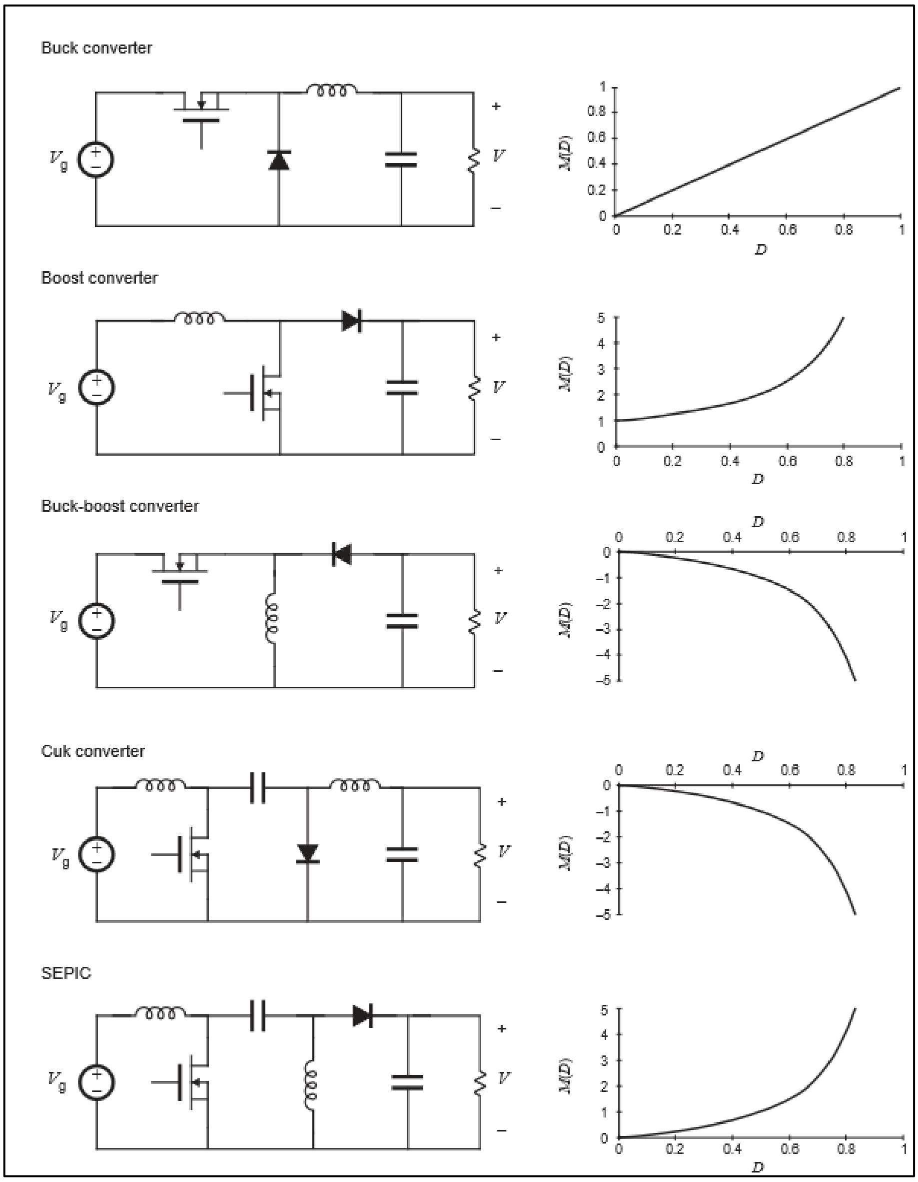

Figure 2.1: Several basic DC-DC converters and their DC conversion ratios.

In each example, the switch is realized using a power MOSFET and diode; however, other semiconductor switches such as IGBTs, BJTS, or thyristors can be substituted if desired.

The first converter is the buck converter. It main ability is reducing the DC voltage and has a conversion ratio of $M(D) = D$. In an equal topology known as the boost converter, the positions of the switch and inductor are swiped. This converter produces an output voltage that is greater in magnitude than the input voltage. Its conversion ratio is $M(D) = 1/(1 - D)$.

In the buck-boost converter, the switch alternately connects the inductor across the power input and output voltage. The output voltage polarity will be inverted and its magnitude can be either increased or decreased. The conversion ratio is $M(D) = -D/(1 - D)$.

The Cúk converter consists of inductor in series with the converter input and output ports. The switch network alternately connects a capacitor to the input and output inductor. The conversion ratio is similar to that of the buck-boost converter. This result in the same function for both of these circuit.

The single-ended primary inductance converter (SEPIC) can also either increase or decrease the voltage magnitude. However, it does not invert the polarity. The conversion ratio is $M(D) = D/(1-D)$.

2.3 Bidirectional DC-DC Converter (Texas Instrument)

Whenever there is a need of bidirectional power flow is needed, Bidirectional DC-DC converters are used. In hybrid electric vehicles (HEVs) and electric vehicles (EVs), these bidirectional converters charge a low voltage (12V) battery during normal operation (buck mode) and charge or assist the high-voltage (400V/600V) battery or bus in emergency situations like when a high-voltage battery has discharged to a very low energy or capacity level (boost mode). A typical system consists of a full-bridge power stage on the high-voltage (HV) side, which is isolated from a full-bridge or a current-fed push-pull stage on the low voltage (LV) side [5].

In this application, TI 32-bit microcontroller TMS320F28035 is used to implement closed-loop control for both directions. This microcontroller is placed on the LV side. Traditionally, microcontrollers have been restricted to performing only supervisory or communications tasks in these systems. Microcontrollers can close control loops in these systems and handle the traditional microcontroller functions with the availability of high-performing microcontroller devices, the transition to digital power control indicates that functions previously implemented in hardware are now implemented in software. In addition to the flexibility, this capability adds to and simplifies the system. These systems can implement advanced control strategies to optimally control the power stage under different conditions and also provide system level intelligence to make safe and seamless transitions between operation modes and pulse width modulated (PWM) switching patterns.

2.3.1 Basic Operation

In Buck mode, a PSFB converter consists of four power electronic switches (like MOSFETs or IGBTs) that form a full bridge on the primary side of the isolation transformer and diode rectifiers or MOSFET switches for synchronous rectification (SR) on the secondary side. This topology let all the switching devices to switch with zero-voltage switching (ZVS) and will result in lower switching losses and an efficient converter.

Signal rectification is required on the secondary side for such an isolated topology. For systems with low output voltage and/or high-output current ratings, implementing synchronous rectification achieves the best performance by avoiding diode rectification losses. In this work, synchronous rectification is implemented on the secondary side with various switching schemes to achieve optimum performance under varying load conditions.

A DC-DC converter system can be controlled in a lot of modes like voltage mode control (VMC), average current mode control (ACMC), or peak current mode control (PCMC). Typically, redesigning the control circuit along with some changes to the power stage sensing circuitry is required to implementing these different control modes for controlling the same power stage. With a microcontroller-based system, all these modes can be experimented with on the same design with minimal or no additional changes. Figure 2.2 shows a simplified circuit of a phase-shifted full bridge. MOSFET switches Q1, Q2, Q3, and Q4 form the full bridge on the primary side of the T1 transformer. Q1 and Q4 are switched at 50% duty and 180 degrees out of phase with each other. QC and QD are switched at 50% duty and 180 degrees out of phase with each other. The PWM switching signals for leg Q2–Q3 of the full bridge are phase-shifted with respect to those for leg Q1–Q4. This phase shift amount will decides the amount of overlap between diagonal switches, which decides the amount of energy transferred. D5 and D6 provide diode rectification on the secondary, while Lo and Co form the output filter. Inductor LR provides assistance to the transformer leakage inductance for resonance operation with MOSFET capacitance and facilitates zero voltage switching (ZVS). Figure 2.3 provides the switching waveforms for the system in Figure.

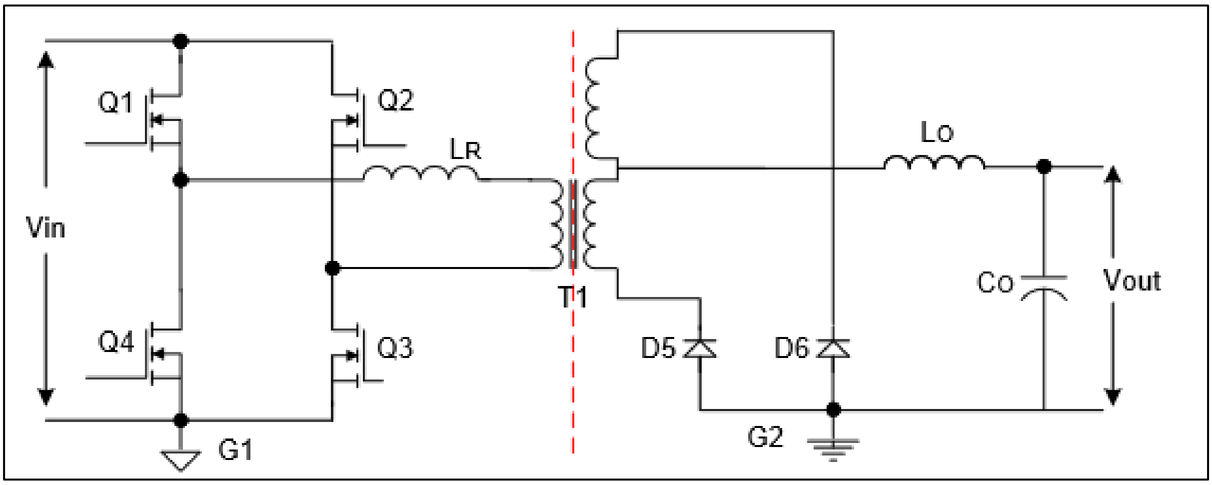

Figure 2.2: Buck mode power stage.

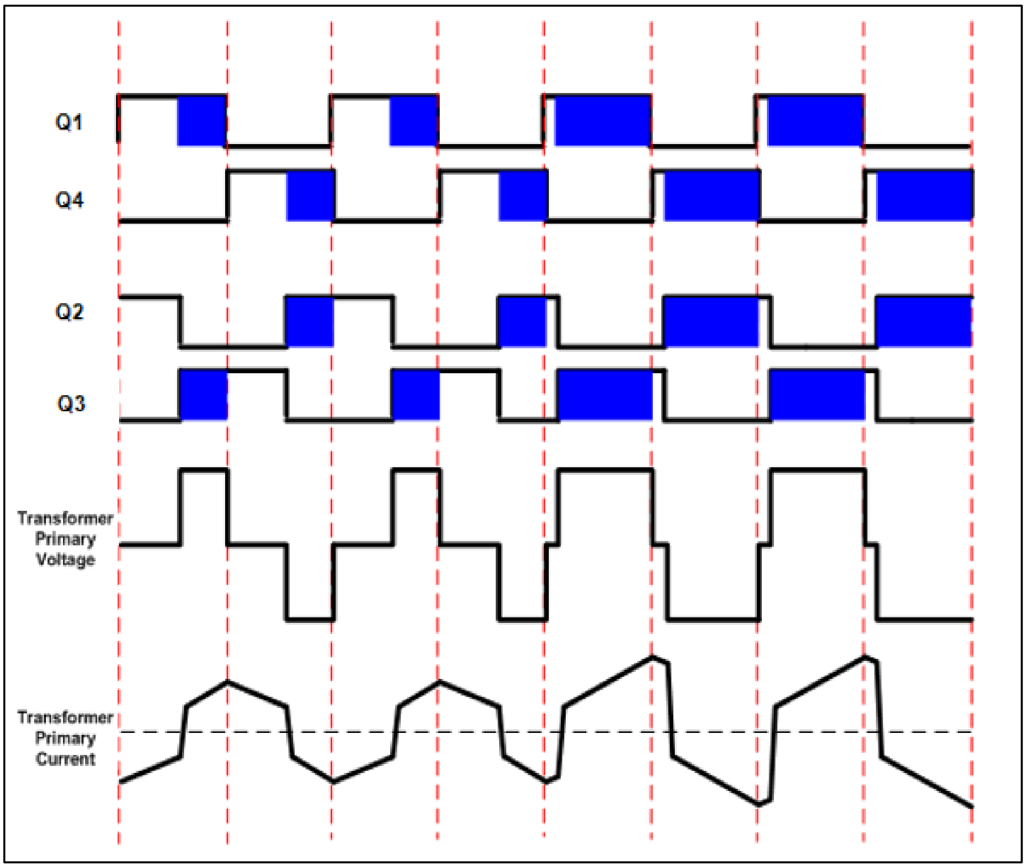

Figure 2.3: Switching waveform.

In boost mode, the synchronous rectifier switches are the push-pull switches. This topology work as a current-fed push-pull converter when the buck mode output inductor acts as a current source in this mode letting. Full-bridge switches on the HV side may be kept off and their body diodes used for rectification. The full-bridge switches are used for active rectification in the boost mode. The push-pull switches are driven with PWM signals with